Implications of crystallization experiments on a parental melt of ALH 77005. C. L. Calvin[1] and M. J. Rutherford[1], [1]Brown University (324 Brook St, Box 1846, Providence, RI, 02912. Email: Christina_Calvin@brown.edu.)

Introduction: The parental melt of a rock is a melt from which a rock began crystallization. Defining the parental melt can provide insight into the compositeon of the source region from which a rock was generated. In addition, once a parental melt has been identified, several other facts about the petrogenesis of the rock can be explored such as the depth of crystallization, the crystallization sequence, and the hydration state of the magma. This study describes and interprets crystallization experiments on a parental melt of ALH 77005.

The Parental Melt of ALH 77005: The parental melt was determined from chromite-hosted melt inclusions [1]. Petrographic studies of ALH 77005 show that chromite was the first phase on the liquidus, followed closely by olivine that poikilitically enclosed the chromite [2]. Electron microprobe analyses of the re-homogenized melt inclusions confirms this interpretation in that the chromite-hosted melt inclusions are more primitive (higher MgO content) than the olivine-hosted melt inclusions as shown in Figure 1. Therefore, we performed crystallization experiments on the chromite-hosted melt inclusion (parental melt) composition shown in Table 1.
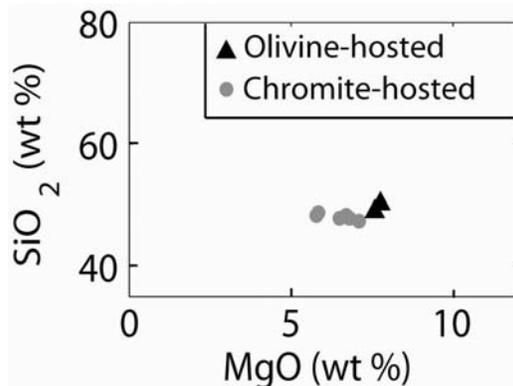

Figure 1. MgO vs. SiO_2 for rehomogenized olivine- and chromite-hosted melt inclusions.

Crystallization Experiments: Crystallization experiments were performed under hydrous and anhydrous conditions in TZM pressure vessels. The anhydrous experiments were run with a pressed pellet of the synthesized parental melt composition which was surrounded by graphite and placed in platinum tubing. The graphite fixes the fO_2 between QFM -2 and -3, consistent with recent studies of the oxygen fugacity of SNC meteorites [3,4,5,6]. Hydrous experiments were similar to the anhydrous experiments except that 1.5 wt % oxalic acid ($H_2C_2O_4 \cdot H_2O$) was added to the capsule containing the pressed pellet. In the hydrous experi-

ments, the platinum capsule was then placed in a second platinum tube that contained NiNiO following the buffer technique described in [7].

Both the hydrous and anhydrous experiments were run at a variety of pressures ranging from 350 bars to 2000 bars. The samples were taken above the liquidus before lowering the temperature over a period of hours to the final crystallization temperature. The final temperature was higher (1145 to 1185°C) for anhydrous experiments than for hydrous experiments (1110 to 1145°C).

Results of Crystallization Experiments: In all experiments, chromite crystallized first. Experiments performed at high pressure then crystallized low-Ca pyroxene followed by plagioclase. Experiments performed at low pressure crystallized olivine, followed by low-Ca pyroxene and eventually high-Ca pyroxene and plagioclase. Representative mineral phases are shown in Table 1. There was little difference in the mineral compositions between the hydrous and anhydrous experiments. However, olivine appeared on the liquidus at higher pressures (500 bars) in the hydrous experiments than in the anhydrous experiments (< 400 bars).

	Parental Melt	Olivine (Dry) (Wet)		Low-Ca Pyx (Dry)	(Wet)
SiO_2	48.96	36.54	37.70	53.19	52.49
TiO_2	2.79	0.12	0.08	0.47	0.62
Al_2O_3	11.79	0.07	0.06	0.99	1.75
Cr_2O_3	1.35	0.15	0.15	0.61	0.75
FeO	14.85	27.39	24.68	15.24	14.85
MnO	0.41	0.00	0.03	0.00	0.03
MgO	7.58	34.94	36.65	22.93	23.87
CaO	9.54	0.46	0.29	5.80	4.57
Na_2O	2.25	0.01	0.03	0.08	0.07
P_2O_5	1.10	--	--	--	--
K_2O	0.12	0.00	0.00	0.01	0.01
Mg #	46	68	72	72	73
Total	100.76	99.68	99.69	99.39	99.012

Table 1. Parental melt and starting composition along with anhydrous (dry) and hydrous (wet) mineral compositions from crystallization experiments.

Verification of parental melt composition: The crystallization experiments verify the parental melt composition determined by [1]. Three lines of evidence support this conclusion. 1) The composition of the crystallized minerals in these experiments replicates

those in the natural rock. 2) The crystallization sequence that appears in the natural rock [2, 8] is reproduced in the crystallization experiments. 3) The evolution of the magma in the crystallization experiments mirrors the evolution of the magma in olivine hosted melt inclusions from [1]. This is shown in Figure 2 where the normative mineralogy of the parental melt is plotted with the composition of rehomogenized olivine-hosted melt inclusions and the residual melt from both hydrous and anhydrous crystallization experiments. The parental melt composition was saturated in spinel and near-saturated with olivine so it is not surprising that these melts plot within the olivine field.
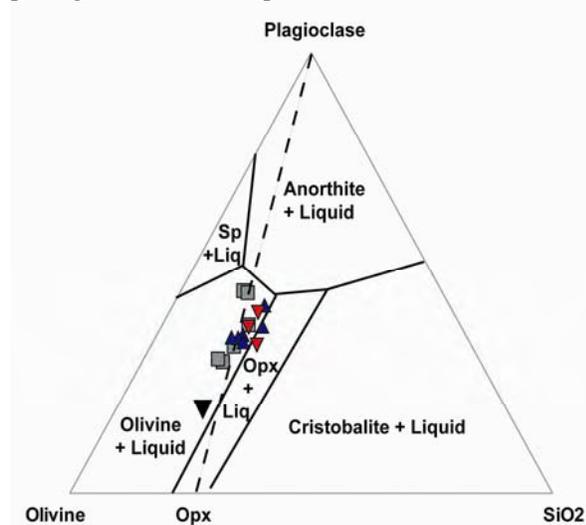

Figure 2: The large black triangle represents the synthesized parental melt composition. Grey squares represent rehomogenized olivine-hosted melt inclusions [1]. Red triangles and blue triangles are residual melt from anhydrous and hydrous crystallization experiments, respectively.

Effect of P_2O_5 and Cr_2O_3 in martian magmas: P_2O_5 (1.1 wt %) and Cr_2O_3 (1.35 wt %) in this parental melt are anomalously high relative to most terrestrial basalts (0.12 wt % P_2O_5 and 0.3 wt % Cr_2O_3 [9]). P_2O_5 and Cr_2O_3 can have a significant influence on the liquidus phases. In basalts, P_2O_5 acts as a network modifying cation in that it competes with SiO_2 for cations such as CaO [10]. Therefore, increases in P_2O_5 increase the number of Si-O-Si bonds in a magma. The result is that the univariant line that separates the olivine and orthopyroxene fields shifts towards olivine favoring the formation of orthopyroxene. However, the increase in P_2O_5 has an additional effect in that it bonds with CaO and thereby decreases the CaO available for pyroxene, thus changing the low-Ca to high-Ca pyroxene ratio in the rock.

Cr_2O_3 also has a significant effect on the liquidus phases in a magma. Small increases in Cr_2O_3 in a magma result in the expansion of the spinel and olivine fields at the expense of the plagioclase and pyroxene fields [11]. Even a small increase in Cr_2O_3 (0.1 wt %) could result in crystallization of olivine rather than pyroxene or plagioclase for a composition near the cotectic.

Depth of crystallization: The results of the crystallization experiments show that olivine can only crystallize at pressures of 400 bars or less. This can be explained through the expansion of the olivine field with decreasing pressure (e.g., [12]). As the pressure decreases, the univariant line between olivine and low-Ca pyroxene crystallization moves toward the pyroxene endmember, expanding the field of olivine crystallization. Since olivine is one of the primary phases in ALH 77005, this suggests that ALH 77005 must have crystallized near the surface of Mars.

Hydration state of ALH 77005: There has been no reported evidence for hydrous phases in ALH 77005; therefore additional evidence must be drawn upon to identify the hydration state of this magma. In terrestrial systems, introducing water into the magma has the effect of changing the crystallization sequence and the composition of the liquidus phases (e.g., [13,14]). However, the low fO_2 at which ALH 77005 is believed to have formed suggests the activity of water in the parental magma should be low [3,4,5,6]. This explains the similarity between the results of the hydrous and anhydrous experiments. At vapor saturation in the hydrous experiments, the fH_2O makes up considerably less than 10 % of the total gas species present [6]. The result is that in the early stages of crystallization, the activity of water was so low as to have little effect on the order or composition of crystallization in the magma. This suggests that even if the parental melt of ALH 77005 was saturated with a C-O-H gas, the low fH_2O would not have caused significant differences in crystallization.

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